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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Detection of hypotension during spinal anesthesia for caesarean section with continuous non-invasive arterial pressure monitoring and intermittent oscillometric blood pressure monitoring in patients treated with ephedrine or phenylephrine

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SUMMARY

Introduction/Objective Despite frequent side effects such as hypotension, spinal anesthesia (SA) is still one of the best anesthetic methods for elective cesarean section (CS). Intermittent, oscillometric, non-invasive blood pressure monitoring (NIBP) frequently leads to missed hypotensive episodes.
The objective was to compare continuous non-invasive arterial pressure (CNAP) monitoring with NIBP in the terms of efficiency to detect hypotension.

Methods In this study, we compared CNAP and NIBP monitoring for hypotension detection in 76 patients divided into two groups of 38 patients treated with ephedrine (E) or phenylephrine (P), during three-minute intervals, starting from SA, by the end of the surgery.

Results In E group, significantly lower mean systolic blood pressure (SBP) values with CNAP compared with NIBP ($p = 0.008$) was detected. By monitoring CNAP, we detected 31 (81.6%) hypotensive patients in E group and significantly lower number, 20 (52.6%), with NIBP ($p = 0.001$), while in P group CNAP detected 34 patients (89.5%) and NIBP only 18 (47.3%), $p = 0.001$. By monitoring CNAP, we detected significantly higher number of hypotensive intervals in E and P groups ($p < 0.001$). Umbilical vein pH was lower within hypotensive compared with normotensive patients in E and P groups, with CNAP and NIBP, respectively ($p < 0.001$, $p = 0.027$ in E, and $p = 0.009$, $p < 0.001$, in P group).

Conclusion CNAP is more efficient in hypotension detection for CS during SA, which allows faster treatment of hypotension, thus improving fetal and maternal outcome.

Keywords: spinal anesthesia; cesarean section; hemodynamic monitoring; hypotension

INTRODUCTION

Spinal anesthesia (SA) is the method of choice for elective cesarean section (CS) despite the fact that it can cause various side effects such as hypotension [1–9]. General anesthesia due to possible difficult intubation and aspiration can lead to the numerous complications [1].

During CS, SA causes hypotension in approximately 50–90% of patients [2, 10] because of the sympathetic blockade [6]. Hypotension is usually accompanied by maternal nausea, vomiting, shivering, respiratory and neural problems [8]. Hypotension leads to the reduction in utero-placental blood flow, and umbilical blood acidosis which can reflect on the vitality of the newborn, Apgar score. Because of potential maternal and fetal side effects, hypotension must be treated immediately, which implies to the significance of more frequent and precise monitoring of maternal blood pressure (BP) [8, 10].

Hypotension can be overcome by using different vasopressors. Phenylephrine increases venous constriction and arterial constriction binding to α1v and α1a adrenergic receptors, which increases BP [5, 11, 12, 13]. Ephedrine is non-catecholamine sympathomimetic agent, acting through α, β1, and β2 adrenergic receptors. Ephedrine has predominant indirect mode

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of action, which explains its relatively slow and prolonged effect [5, 11, 12].

During the past years, continuous non-invasive arterial pressure (CNAP) monitoring is being used in obstetrics, but not routinely. CNAP monitor use allows that side effects of SA during the caesarean section can be minimized or avoided by rapid detection of BP changes. The CNAP monitor uses volume clamp method described by Penáz et al. [14] as "vascular unloading." CNAP measure blood volume in an artery and kept constant by applying external pressure. Changes in external pressure keep the arterial blood volume constant and corresponds to the changes of arterial pressure [15]. CNAP monitor is not used in patients with aortic regurgitation, arterial vascular disease, hypothermia, low perfusion index – PI < 1. Hemodynamic parameters measurement by classic NIBP monitor might reduce the chance of recurrent hypotensive episode to be detected and thus avoided. There is no clinical guideline for optimal NIBP cycles. Most of the studies analyzed one- to five-minute cycles. Often NIBP measurement causes discomfort in patients due to the arm clamping [16]. If a precise BP measurement is required, continuous invasive BP monitoring is used, which involves the placement of an arterial line.

The main goal of this study was to investigate differences between two different types of monitoring: NIBP and CNAP in the terms of number of detected hypotensive episodes and maternal and newborn characteristics, and to see which of the technique is more confident and reliable. Our hypothesis is that CNAP might detect higher number of hypotensive episodes, compared with NIBP.

METHODS

The study was performed as comparative, prospective, and randomized. The study was conducted in accordance with the Declaration of Helsinki of 1975, revised, in 2013, and the protocol was approved by the Ethics Committee of the Dr Dragiša Mišović – Dedinje University Hospital Center in Belgrade no. 01-5293/23. All patients, 76 in total, gave their written informed consent. All patients were of American Society of Anesthesiologists (ASA) 1 or 2 physical statuses. The subjects were primiparous or multiparous patients in the term pregnancy. All patients were scheduled for elective CS, according to obstetric indications and had been examined by the anesthesiologist the day before surgery. Inclusion criteria were; age of the patients between 18 and 40, one fetus, body weight between 50 and 100 kg, and height 150 cm or higher, difference between arterial pressure of the left and right arm have not exceeded 5 mmHg, while exclusion criteria were: less than 36 weeks gestation, cardiovascular diseases, pre-eclampsia, hypertension, and contraindications for SA. The patients were divided into two groups of 38 each, and selected to receive either ephedrine or phenylephrine by a computer-generated randomization table.

Ephedrine, (Galenica Senese, Monteroni d'Arbia, Italy), E group received infusion at a 5 mg/min immediately after SA during the first three minutes. In the cases of more than 20% of the drop of systolic blood pressure (SBP) than the baseline, rescue bolus dose of 5 mg of ephedrine was given intravenously (IV). Then, the infusion was continued. If SBP values increased more than 20% of baseline values, the infusion was interrupted.

Phenylephrine (Sintetica Spinal Anesthesia, Sintetica, London, United Kingdom), P group received infusion at a 25 μg/min dose, starting two minutes prior to SA, and for the next three minutes. In the cases of reduced SBP more than 20% of baseline the patients received rescue bolus dose of 50 μg of phenylephrine, intravenously and infusion was continued. In the cases of bradycardia, the patients received 0.5 mg atropine, intravenously. If SBP was higher than 20% of baseline, phenylephrine infusion was aborted. Both infusions were administered via infusion pump (Argus 600S, Argus Medical AG, CH 3627 Heimberg, Switzerland).

Patients were in the supine position, with the operating table tilted 15 degrees to the left.

In our cohort, heart rates (HR) lower than 60 per min were defined as bradycardia. The drop of SBP values for more than 20% of baseline value was defined as hypotension, while the increase of more than 20% of baseline SBP value was defined as hypertension.

All patients were treated with 50 mg of ranitidine intravenously, one hour preoperatively through an IV cannula inserted into the right arm. All patients received 500 ml of Hartmann's solution before entering the operating room and antibiotic 30 min preoperatively. During the CS the infusion of Hartmann's solution was resumed. Baseline values of BP, HR, electrocardiogram, and oxygen saturation (SpO_2) were obtained with DASH® 4000 monitor (GE Medical Systems Information Technologies, USA). Mean values of first three successive measurements NIBP on the surgery table were used as baseline values of NIBP, and were recorded every three minutes. NIBP cuff was placed on left arm of the patients.

BP was measured and recorded with LIDCO Rapid^{V2}CNAP (LIDCO Ltd, London, UK) hemodynamic monitor, as well. LIDCO Rapid^{V2}CNAP contains a module for non-invasive continuous monitoring of arterial pressure using a double finger cuff with integrated infra-red (IR) photo sensor and air bag. Measured IR signal allows tracking blood volume in the finger. The finger cuff is consisted of the pressure gauge for measuring pressure for each heartbeat (beat to beat). The graph for continuous BP is recorded by CNAP module and is analyzed by Pulse CO^R algorithm.

Double finger cuff attached to the index and middle finger of the right arm.

The CNAP monitor was calibrated before the first measurement to the value of the arterial BP of the brachial artery measured by the NIBP monitor. Calibration was automatic and manual in the event of a drop in BP when values from the NIBP monitor are entered manually. Lidco Rapid CNAP technology is also reliable during the application of vasoactive drugs because it uses the protected VERIFY algorithm for autocorrection of changes in arterial tone.

Baseline CNAP is represented by mean CNAP value in the first minute after the monitor calibration. Time from CNAP and NIBP monitors were concordant. BP was measured on both hands at each patient's (on the right arm via CNAP, and on left arm via NIBP monitor). Both hands were at heart level. NIBP measured SBP at three-minute intervals. At the same time, at each patient SBP was cyclically compared at both monitors. Hypotension treatment was based on SBP values monitored with CNAP.

Bupivacaine-spinal (Marcaine® Spinal Cenexi-Fontenay), 0.5% 2–2.2 ml, 10–11 mg was given in L3/4 intervertebral space. SA was given with 25 G "pencil point" spinal needle (Pencan® B.Braun Melsungen AG Germany) in the sitting position. Then, the patients were returned to their supine position, with the operating table tilted 15° to the left.

We have analyzed the number of hypotensive patients detected by CNAP and NIBP monitor, in both groups, the number of hypotensive episodes detected by CNAP and NIBP monitor, in both groups, pH analysis of umbilical vein, analysis of Apgar score in the first and fifth minute (HR, respiration, muscle tone, reflex irritability, and skin color). Apgar score was calculated as sum of points (0–10); where each parameter carries 0–2 points.

The power of the study at 90% is the result of the assessment of sample size justification, and has been performed before the start of the study. The sample size was determined by Altman nomogram and confirmed by calculation with the formula was defined with a total of 76 patients. The data collected were processed in SPSS v. 19.0 (IBM Corp., Armonk, NY, USA) software. For statistical analysis we used Kolmogorov–Smirnov normality test, then parametric and non-parametric Student's t-test, Mann–Whitney, Pearson's correlational test, χ^2 test, and Fisher's exact test for analysis of frequency distribution; p values < 0.05 were considered as significant.

RESULTS

In this cohort, we investigated 76 patients planned for CS under SA, treated with two different vasopressors, 38 treated with ephedrine and 38 treated with phenylephrine. In both groups we analyzed and compared 1500 intervals measurements SBP (750 per group) in three-minute intervals starting with SA, up to the end of the delivery and surgery. Mean time of data collection was 59 min per patient.

Table 1. Patient characteristic data

Characteristics	Group ephedrine (n = 38)	Group phenylephrine (n = 38)	p
Age (year)	32 (4)	30.9 (3.6)	0.203
Weight (kg)	82.1 (9.8)	74.8 (8.8)	0.003*
Height (cm)	169.7 (5.2)	166.9 (6.3)	0.064
Gestational age (weeks)	38.8 (0.5)	38.8 (0.6)	0.692
Parity	2 (1–3)	2 (1–3)	-
ASA Class I	24 (63.2%)	24 (63.2)	-
ASA Class II	14 (36.8%)	14 (36.8)	-

*significant p < 0.05, mean (SD), median (min–max), n (%); Student's t-test, χ^2 test; ASA – American Society of Anesthesiologists

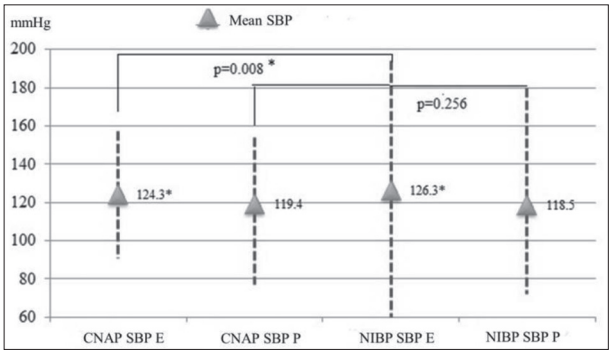

Figure 1. Comparison of mean SBP between E and P groups. Mean systolic blood pressure (SBP) in mmHg measured with CNAP and NIBP methods in ephedrine (E) and phenylephrine (P) groups; CNAP – continuous non-invasive arterial pressure; NIBP – non-invasive blood pressure monitoring; p-values < 0.05 were considered as significant and is presented by *.

Patient characteristics were shown in Table 1. Patients from E group were of greater body weight (p = 0.003).

Table 2. shows fetal characteristics measured by the two methods (CNAP or NIBP) in hypotensive and normotensive patients within E and P groups. Umbilical vein pH was lower within hypotensive compared with normotensive patients in E and P groups, with CNAP and NIBP, respectively (p < 0.001, p = 0.027 in E, and p = 0.009, p < 0.001, in P group) (Table 2). Apgar score in the first and fifth minute did not change significantly, when compared hypotensive and normotensive patients in E and P groups

Table 2. Fetal outcome (pH and Apgar score) in normotensive and hypotensive patients within ephedrine and phenylephrine groups

Group Ephedrine	Continuous non-invasive arterial pressure device		Intermittent oscillometric arterial pressure measurement			
	normotensive	hypotensive	p	normotensive	hypotensive	p
pH	7.381 (0.055)	7.342* (0.065)	< 0.001	7.365 (0.030)	7.359* (0.040)	0.027
Apgar minute 1	9 (8–9)	9 (8–9)	-	9 (8–9)	9 (8–9)	-
Apgar minute 5	10 (9–10)	10 (9–10)	-	10 (9–10)	10 (9–10)	-
Group Phenylephrine	Continuous non-invasive arterial pressure device (CNAP)		Intermittent oscillometric arterial pressure measurement (NIBP)			
	normotensive	hypotensive	p	normotensive	hypotensive	p
pH	7.363 (0.063)	7.337* (0.067)	0.009	7.361 (0.036)	7.341* (0.036)	< 0.001
Apgar 1 minute	9 (8–9)	9 (8–9)	-	9 (8–9)	9 (8–9)	-
Apgar 5 minute	10 (9–10)	10 (9–10)	-	10 (9–10)	10 (9–10)	-

*significant p < 0.05, mean (SD), median (min–max), Student's t-test, Mann–Whitney test

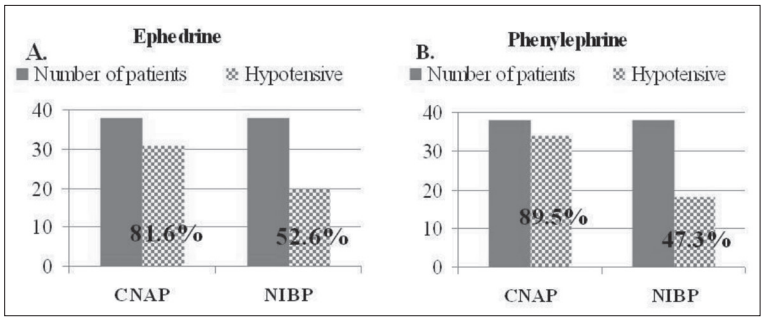

Figure 2. Percentage of hypotensive patients by CNAP and NIBP monitor in E and P groups; the percentage of patients with at least one SBP decline by more than 20% from baseline, detected with CNAP or NIBP in ephedrine (E) and phenylephrine (P) groups; CNAP – continuous non-invasive arterial pressure; NIBP – non-invasive blood pressure monitoring

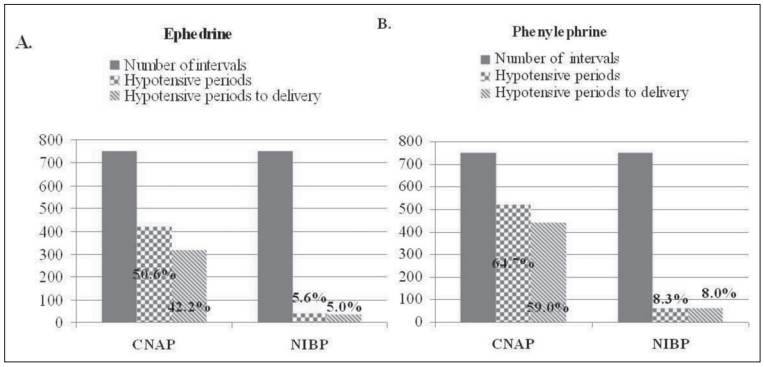

Figure 3. The incidence of hypotensive episodes in E and P groups by CNAP and NIBP monitoring. Incidence of hypotensive episodes in the period from spinal anesthesia to the end of the surgery and in the period from spinal anesthesia to the delivery in A-ephedrine (E), and B-phenylephrine (P) groups with CNAP and NIBP monitors;
CNAP – continuous non-invasive arterial pressure; NIBP – non-invasive blood pressure monitoring

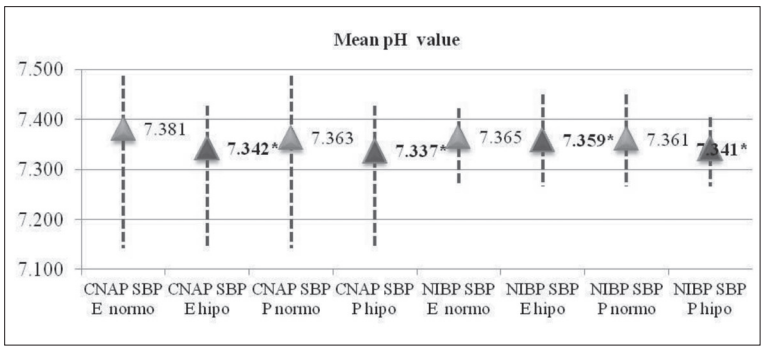

Figure 4. Umbilical vein pH differences within hypotensive and normotensive groups between CNAP and NIBP monitors; mean umbilical blood pH values within normo and hypotensive patients in ephedrine (E) and phenylephrine (P) monitored with CNAP and NIBP monitor; CNAP – continuous non-invasive arterial pressure; NIBP – non-invasive blood pressure monitoring; significant $p < 0.05$ is presented by *.

on both monitors (Table 2). Mean values SBP measured with both monitors in E and P groups were presented in Figure 1. We detected significantly higher SBP values in E group, measured by both CNAP and NIBP methods (124.3 CNAP and 126.3 NIBP), compared with P group (119.4 CNAP and 118.5 NIBP), with $p < 0.001$.

In E group, we detected significantly lower mean SBP values with CNAP compared with NIBP ($p = 0.008$, Figure 1). In P group, we did not detect any difference in SBP values between two methods ($p = 0.256$, Figure 1).

Percentage of hypotensive patients by CNAP and NIBP monitor in E and P groups was shown in Figure 2. In E group by CNAP method, 31 (81.6%) patients experienced hypotension, while significantly lower number of patients experienced hypotension, according to NIBP monitoring, 20 (52.6%), ($p = 0.001$, Figure 2). In P group, hypotension was detected within 34/38 (89.5%) patients by CNAP monitoring, while according to NIBP monitoring 18 (47.3%) patients had hypotension ($p = 0.001$, Figure 2).

In E group, during the 750 measurements of SBP per every 3 min, hypotension was detected in 420 (50.6%) measurements with CNAP, while only in 42 (5.6%) measurements with NIBP ($p < 0.001$, Figure 3). In P group, CNAP monitor detected hypotension in 521 (64.7%) cycles of measurement, while with NIBP only 62 (8.3%) measurements indicated hypotension ($p < 0.001$, Figure 3).

Significantly higher incidences of hypotensive intervals were detected to the moment of the delivery with CNAP monitor (42.2% hypotensive episodes in E group and 59% in P group, i.e., in 83.3–91.2% of cases, Figure 3). NIBP monitor did not show any significant differences in both groups. (5% hypotensive episodes in E group and 8% in P group, i.e., in 89–96% of cases, Figure 3). In the cases of hypotensive periods to delivery, CNAP showed significantly higher number compared with NIBP in both, E and P groups ($p < 0.001$, Figure 3).

Mean values of umbilical vein pH were lower within hypotensive compared with normotensive patients in E and P groups, with CNAP and NIBP measurements, respectively ($p < 0.001$, $p = 0.027$ in E, and $p = 0.009$, $p < 0.001$, in P group) (Figure 4).

Additionally, we performed correlational analysis between E and P groups (Table 3), which additionally confirms results from umbilical pH analysis presented on Figure 4. Lower pH values within hypotensive patients are confirmed in correlational analysis. We detected negative correlation with moderate correlational coefficient -0.468 with very low p value ($p < 0.001$, Table 3, Pearson's product moment) between mean pH values and number of hypotensive episodes on E group, which means that higher number of hypotensive episodes might be associated with lower pH values in E group and *vice versa*.

DISCUSSION

Up to now, there has been no precise definition of hypotension in the literature and practice. Majority of the studies

Table 3. Associations between SBP, hypotension incidence, and pH in E and P groups

Parameter	pH E	pH P
SBP	**rho = 0.161****	**rho = -0.116****
	p < 0.001	**p = 0.002**
ΔSBP	**rho = -0.236****	rho = -0.035
	p < 0.001	p = 0.358
Incidence of hypotension (number of patients)	**rho = -0.468****	**rho = -0.108****
	p < 0.001	**p = 0.004**
Incidence of hypotension in number of intervals	**rho = -0.100****	rho = 0.046
	p = 0.006	p = 0.216

Correlation at the 0.01 level (2-tailed)-** was considered as significant; SBP – systolic blood pressure; E – ephedrine; P – phenylephrine; Pearson's correlational test

use the drop of 20% of baseline BP, or use the value of systolic BP below 100 mmHg as hypotension [17]. Besides the hypotension definition, type of monitoring also may impact on efficiency of hypotension detection and thus its prevention and treatment [10, 18, 19]. Stenglova and Benes [19] reviewed and emphasized that even a short period of hypotension, especially if they are more frequent, may significantly influence on postoperative recovery.

Ilies et al. [10], Juri et al. [18] are among the first authors who compared differences in number of hypotensive episodes between continuous and intermittent monitoring.

Although hemodynamic changes during CS have already been measured continuously [10, 18, 20, 21], to the best of our knowledge, this is the first study that investigates differences in hypotensive episodes by using DASH® 4000 monitor, non-invasive intermittent oscilloscopic compared with parameters measured with continuous LIDCO Rapid^{V2}CNAP monitoring system within the patients treated with E and P vasopressors.

Juri et al. [18] compared ClearSight™ system (Edwards Lifesciences, Irvine, CA, USA) with classical BP monitoring within 40 patients and have shown ClearSight™ system use resulted in lower rates of hypotension and nausea than use of regular oscillometric BP monitor.

Han et al. [16] give the advantage to CNAP monitoring compared with NIBP monitoring in the hemodynamic stability maintenance, and maternal and fetal outcome. Their study has shown similar incidence of detected hypotensive periods in both groups (NIBP-N and CNAP-C). Significantly lower incidence of severe hypotension was detected in C group, because it was significantly earlier discovered and treated.

In our research, we have compared results of SBP and umbilical vein pH measured with both, CNAP and NIBP monitoring systems. Interestingly, we detected significantly lower mean values of SBP with CNAP compared with NIBP measurement in E group, but not in P group. Number of hypotensive patients significantly differed between CNAP and NIBP in both, E and P groups. In E group, according to CNAP monitor, 81.6% of patients experienced hypotension, and 52.6% according to NIBP, while in P group, CNAP detected 89.5%, and NIBP only 47.3% hypotensive patients. Similarly, Ilies et al. [10], compared two techniques CNAP by CNAPTM Monitor 500, (CNSystems Medizintechnik, Graz, Austria), and oscillometric [non-invasive arterial pressure measurement, (NIAP)]. They also showed that CNAP detected lower values of BP, than NIAP. CNAP detected hypotension, within 91% patients, while NIAP only within 55%. Of the total number of three-minute intervals, CNAP detected 39% as hypotensive and NIAP 9%. This may be due to differences in protocols, differences in vasopressors used, and their mode of application.

In our research, we have also measured number of hypotensive episodes up to the end of the surgery, where we have also found significantly higher number detected with CNAP compared with NIBP in both, E and P groups.

Numerous studies have shown that hypotension leads to the decrease in pH umbilical blood [22] or a lower Apgar score [23].

Similarly, Ilies et al. [10], in our research, mean umbilical vein pH values were lower within hypotensive patients, on both, CNAP and NIBP in E and P groups. Apgar scores at the first and fifth minute were not different between hypotensive and normotensive mothers.

The major limitation of the study was that we measured SBP at three-minute intervals. But, if we had been measuring with one- or two-minute intervals with NIBP, discomfort of patients would be much greater.

CONCLUSIONS

This study has found that hypotension during CS is more readily detected with CNAP than with NIBP monitor. Our results showed that in both examined groups of vasopressors on both monitoring systems, lower pH values were detected within hypotensive patients.

Continuous monitoring enables clinicians to track and detect hypotension more precisely and efficiently than intermittent. Not only the type of monitoring is important, but also the type of vasopressor, as well. Further researches are needed which will involve much detailed information on hemodynamic changes and patients' outcome at different time points during the surgical procedure.

Conflict of interest: None declared.

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Откривање хипотензије током спиналне анестезије за царски рез континуираним неинвазивним праћењем артеријског притиска и интермитентним осцилометријским праћењем крвног притиска код болесница третираних ефедрином или фенилефрином

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САЖЕТАК

Увод/Циљ Упркос честим нежељеним ефектима као што је хипотензија, спинална анестезија је и даље техника избора за планирани царски рез. Интермитентно неинвазивно праћење крвног притиска често не детектује хипотензивне епизоде. Циљ ове студије је био да се упореди континуирано неинвазивно праћење артеријског притиска са интермитентним неинвазивним праћењем крвног притиска у смислу ефикасности у откривању хипотензије.

Методе Упоређивани су системи за континуирано неинвазивно праћење артеријског притиска и интермитентно неинвазивно праћење крвног притиска ради детекције хипотензије код 76 болесница подељених у две групе од по 38 болесница, третираних ефедрином (Е) или фенилефрином (Ф), на свака три минута, почевши од спиналне анестезије па све до краја операције.

Резултати У групи Е су детектоване знатно ниже средње вредности систолног крвног притиска континуираним неинвазивним праћењем артеријског притиска у поређењу са интермитентним неинвазивним праћењем крвног притиска ($p = 0,008$). Континуираним неинвазивним праћењем артеријског притиска детектована је 31 (81,6%) хипотензивна болесница у групи Е и знатно мањи број, 20 (52,6%) болесница, интермитентним неинвазивним праћењем крвног притиска ($p = 0,001$), док је у групи Ф континуираним неинвазивним праћењем артеријског притиска детектована хипотензија код 34 болеснице (89,5%), а интермитентним неинвазивним праћењем крвног притиска код 18 (47,3%) болесница, $p = 0,001$. Континуираним неинвазивним праћењем артеријског притиска детектован је знатно већи број хипотензивних епизода у групама Е и Ф ($p < 0,001$). *pH* вредности умбиликалне крви биле су значајно ниже код хипотензивних у односу на нормотензивне болеснице у групама Е и Ф, и са континуираним неинвазивним праћењем артеријског притиска и интермитентним неинвазивним праћењем крвног притиска, респективно ($p < 0,001$, $p = 0,027$ у групи Е, и $p = 0,009$, $p < 0,001$ у групи Ф).

Закључак Континуирано неинвазивно праћење артеријског притиска је много ефикасније у откривању хипотензије током царског реза у спиналној анестезији, што омогућава бржи третман и мање нежељених ефеката код мајке и новорођенчета.

Кључне речи: спинална анестезија; царски рез; хемодинамско праћење; хипотензија